

NASA/CR-97- 112569

FINAL
7N-114-012
OCIT
083589

An Analysis of the Magneto-Optic Imaging System

NASA Grant Number - NAG 1 1673

Final Report

April 1996

NASA Contact

Dr Min Namkung

M/S 231

(804) 864 - 4962

Submitted by:

Shridhar Nath

CNDE

102 Maryland Hall

Johns Hopkins University

Baltimore, MD 21218

Table of Contents

1. Summary.....	3
2. Tasks Performed	
A. Finite element modeling.....	4
3. Deliverables	
A. Finite element modeling.....	5
B. Image Classification.....	5
C. Image Processing.....	5
4. Future work.....	6
5. Appendix I	
Figure 1. MOI head model with dimensions.....	7
Figure 2. MOI model with the surface cracks.....	8
Figure 3. B_z as a function of excitation current.....	9
Figure 4. B_z as a function of excitation current.....	10

1. SUMMARY

The Magneto-Optic Imaging system is being used for the detection of defects in airframes and other aircraft structures. The system has been successfully applied to detecting surface cracks, but has difficulty in the detection of sub-surface defects such as corrosion. The intent of the grant was to understand the physics of the MOI better, in order to use it effectively for detecting corrosion and for classifying surface defects.

The grant was divided into three categories for undertaking the above task.

A. Finite element analysis

A three dimensional model of the MOI head, rivet and lap joint was set up using the commercial eddy current software from ANSOFT. Surface and sub-surface cracks were modeled. Curves showing the magnetic field as a function of the excitation current for optimizing the sensor were obtained.

B. Image Classification

A neural network (NN) scheme was trained for classifying MOI images. The moments of an edge detected and solid silhouette image of a rivet was used as the feature space for training the neural network. The NN used was a multi-layer perceptron with back propagation algorithm for training. Images obtained from the panels at the FAA NDI Center was used as the training data set and for testing the NN. The results were presented at the Progress in Quantitative NDE conference in Seattle, last August.

C. Image Processing

A number of different image processing schemes was investigated to do "real time" processing on the MOI images for enhancing corrosion images. Information of existing hardware from various vendors was collected and analyzed. A final recommendation of using a real time processing board from Data Translation is made for this task.

TASKS PERFORMED

A. Finite element analysis

Surface cracks of different lengths emanating from a rivet head was modeled with the three dimensional eddy current software ANSOFT. The main intent was to monitor the change in the normal component of the magnetic flux density or magnetic flux as a function of the excitation current. Fig.1 shows the MOI head with the different components and dimensions that has been modeled, while Fig. 2 shows the model with the surface crack.

For a given frequency the excitation current was changed to monitor the magnetic field. Though in the actual MOI unit the current is “on” for a short time (17 % duty cycle), the model uses the quasi-static formulation, thus the excitation is continuous. Fig. 3 and 4 are plots of B_z as a function of current in two different planes for two different crack lengths (2.5 mm and 5 mm lengths measured from the shank area). The sensor is actually at 0.425 mm above the sample (Fig. 1), but it was interesting to visualize the magnetic fields just above the sample. In Fig 5. all the curves are superimposed for a direct comparison. With these figures it is clear that with smaller cracks the change in the normal magnetic field is so small that the sensor has to be sensitive enough to monitor those changes.

The same crack was modeled in the second layer (sub surface) to monitor the B_z field levels at the sensor location. The model was discretized more finely (denser mesh) to minimize the discretization error. Even with nearly 8000 three dimensional elements, the results were not satisfactory. The only way to obtain these results is to break the region into smaller pieces and make the mesh denser. At the same time, denser the mesh, larger is the matrix to solve, which puts a lot of strain on the computing resources. With the present model and resources, it was not possible to get accurate data on sub-surface defects.

3. DELIVERABLES

A. Finite element analysis

The curves of the magnetic field as a function of the excitation current can be used as tool to optimize the MOI sensor. If the sensitivity of the instrument can be achieved with lower current levels, it would reduce the heating loss in the instrument. This could help in redesigning their power supply to make the imaging head lighter and more efficient.

B. Image Classification

A multi-layer perceptron neural network has been developed for classifying images of surface breaking cracks. PRI, Inc., the manufacturers of the MOI instrument are planning to incorporate a PC into the next generation of the instrument. The image classification software can then be part of an analysis software tool along with the instrument.

C. Image Processing

After investigating various image processing boards for doing real time imaging to enhance the corrosion images, it is recommended that the Data Translation board, DT 2867 with the Global Lab software would do the job for a reasonable price. This board has an on-board DSP processor with memory to undertake real time image processing. Other image processing routines used for minimizing the background and enhancing the corrosion image included morphological operators, thresholding and other filtering schemes.

4. FUTURE WORK

Understanding the change in the magnetic field due to sub-surface cracks and corrosion is critical for sensitivity studies for the MOI. Three dimensional finite element analysis with a lot more computational resources is needed for obtaining an accurate solution to model sub-surface corrosion.

Image processing of corrosion images is another area of research that need attention too. One route of improving corrosion images is to undertake the real time imaging mentioned in this report and previous reports. Another route is to undertake large area averaging using a template. This would be computationally simpler, would reduce the background information, but would not be real time. A computer will be needed to grab the images at each location, store it, average it and enhance it further with other imaging processing tools. Again this will have to be done in *near real time* to help the operator make a decision during inspection.

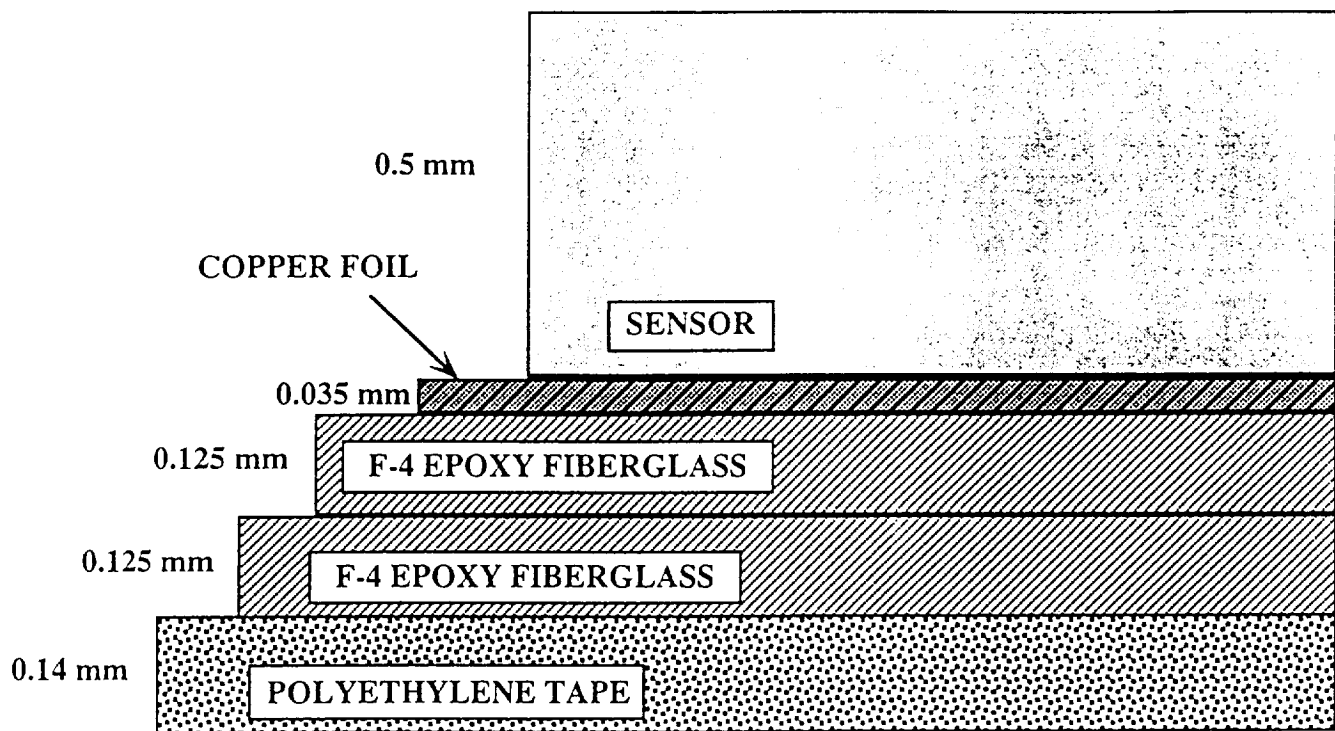


FIG. 1. MOI Imaging head. The active portion of the sensor is a 3.5 microns thick bismuth-doped magneto-optic garnet film shown as a dark piece at the bottom of the sensor. This sensor is 0.425 mm away from the sample under test.

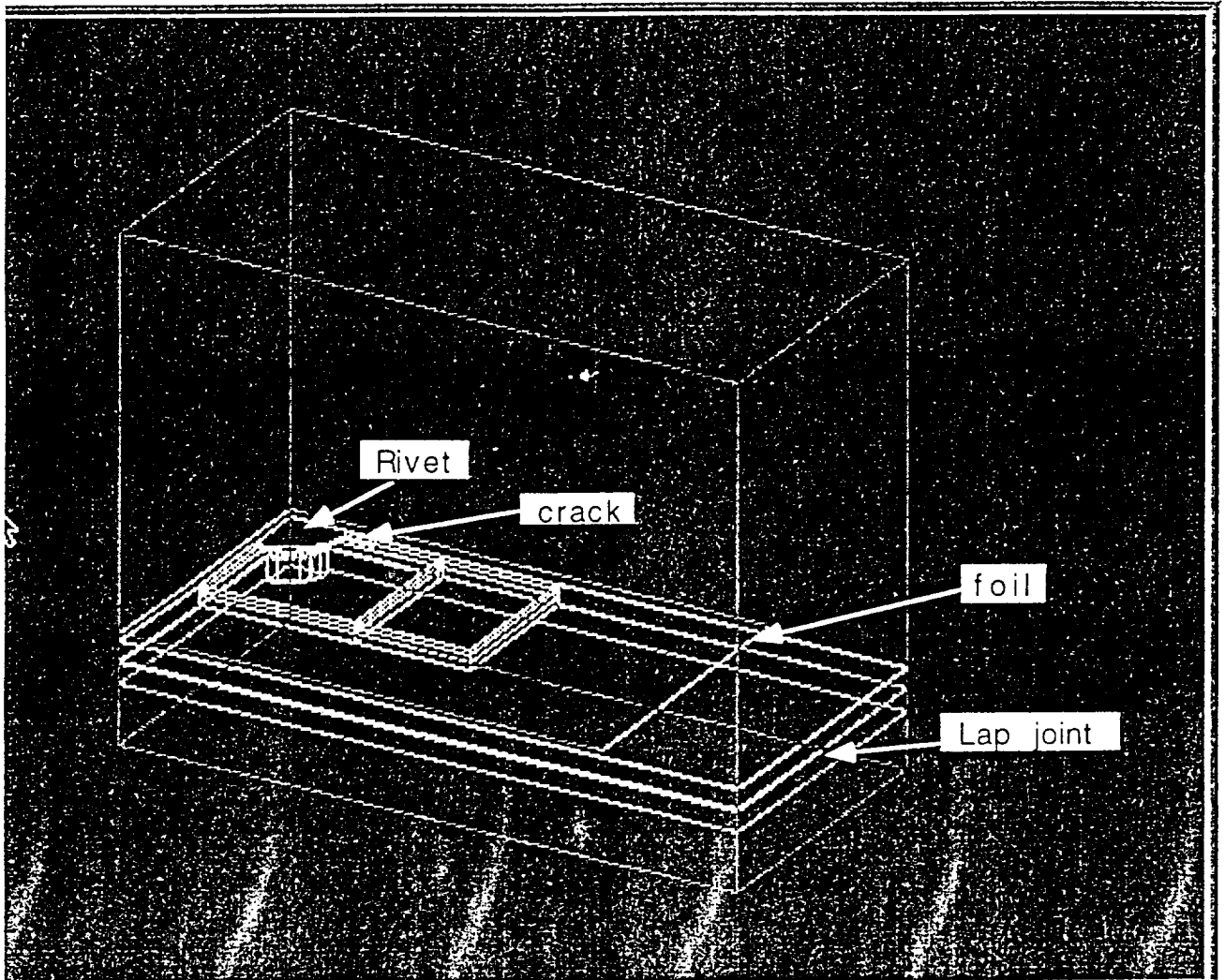


FIG. 2. Finite element model. Quarter symmetry finite element model showing the rivet, copper foil, lap splice and a crack.
Note. Near the rivet the space is divided into smaller plates so as to increase the discretization close to the rivet.

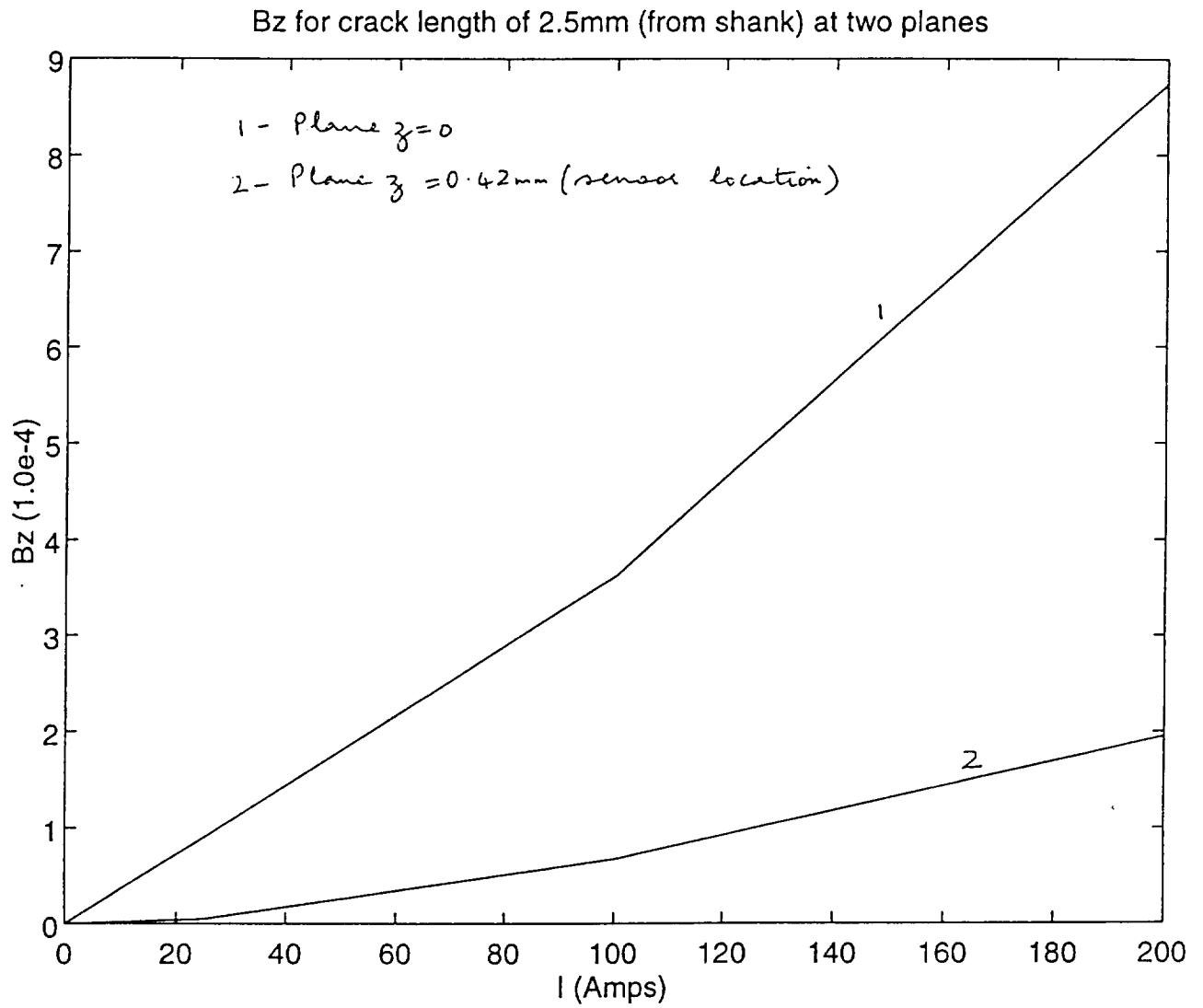


FIG 3. Plot of B_z as a function of excitation current for a crack length of 2.5 mm at planes, $z = 0$ mm and $z = 0.425$ mm (sensor location).

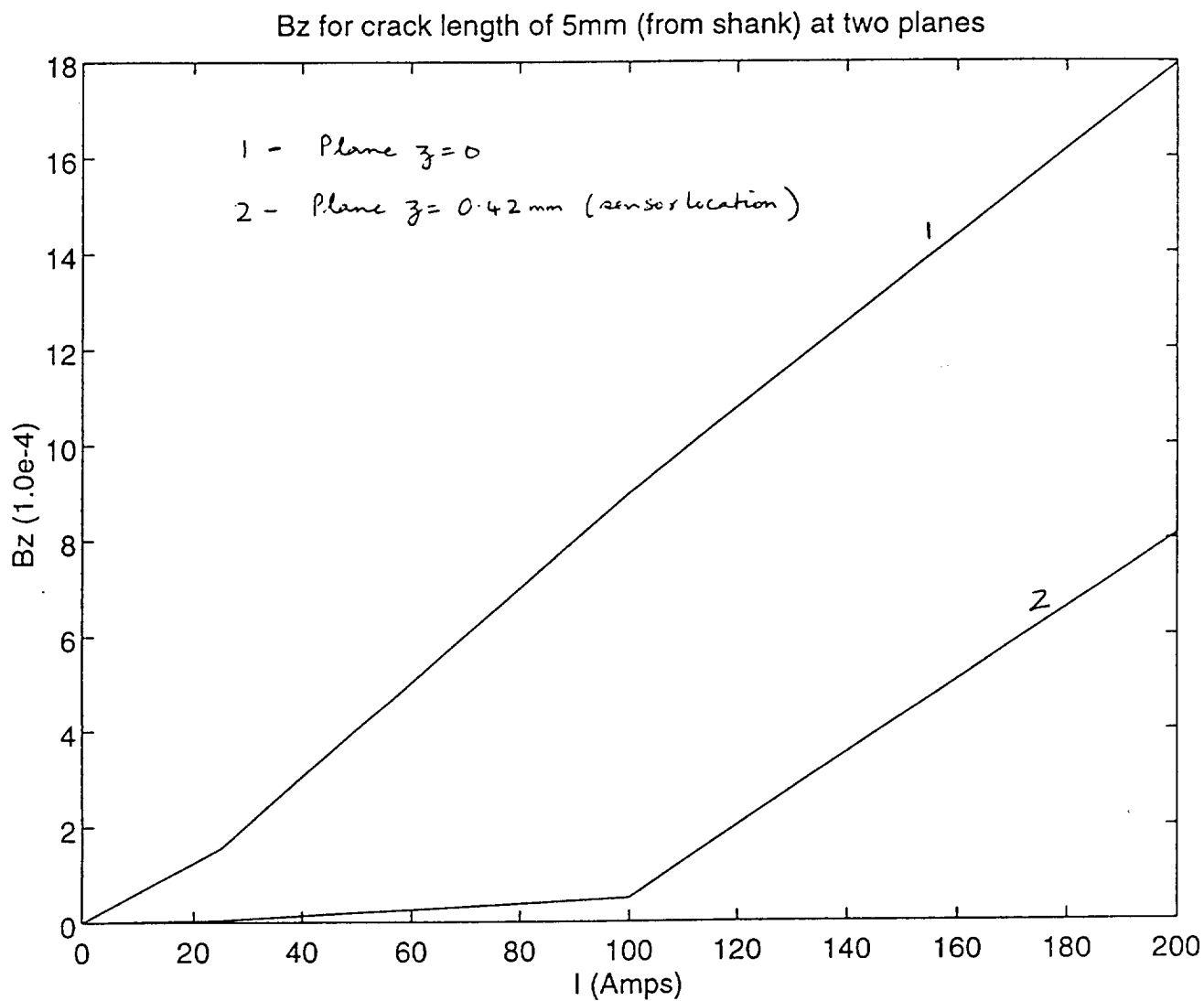


FIG 4. Plot of B_z as a function of excitation current for a crack length of 5 mm at planes, $z = 0$ mm and $z = 0.425$ mm (sensor location).

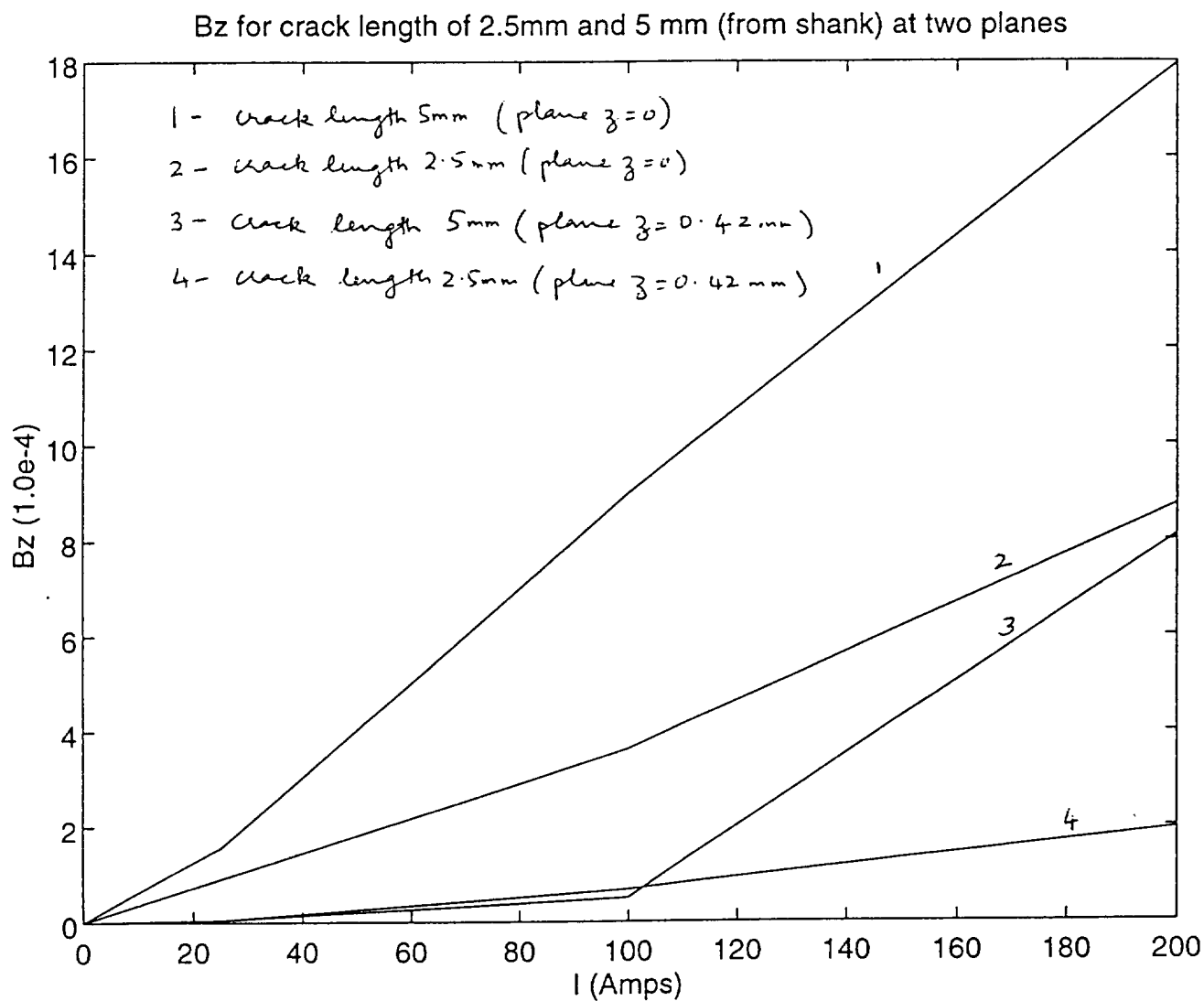


FIG 5. Plot of B_z as a function of excitation current for a crack length of 2.5 mm and 5 mm at planes, $z = 0$ mm and $z = 0.425$ mm (sensor location).